GHANA'S BIOENERGY POLICY: IS 20% BIOFUEL INTEGRATION ACHIEVABLE BY 2030?

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Abstract

In dealing with the climate change externality of the fossil-fuel dominated transport sector, bio-fuels are widely seen as a solution. Through its Bioenergy Policy (DBP), Ghana seeks to improve oil supply security, save foreign exchange, create jobs and reduce emissions from the transport sector by integrating 20% biofuels into the transport fuel mix by 2030. This paper systematically analyses the transport fuel demand in Ghana to determine the biofuel supply target in 2020 and 2030 and evaluates the resource input requirements for integration of biofuels into the transport fuel mix. It provides a detailed picture of bio-fuel prospects in Ghana in the 2030 horizon. The research concludes that though significant yield improvement is required to meet the target, the target is achievable.

Keywords: biofuels, Ghana, forecasting, decomposition analysis.

Table of content

ABBREVIATIONS

ALA	Agricultural Land Area
ATK	Kerosene for aviation
BAU	Business-as-usual
CCS	Carbon Capture and Storage
CO_2	Carbon dioxide
EC	Energy Commission, Ghana
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	Green House Gas
HGS	High growth scenario
IEA	International Energy Agency
Lde	Litres of diesel equivalent
Lge	Litres of gasoline equivalent
LPG	Liquid Petroleum Gas
MGS	Moderate economic growth scenario
MOFA	Ministry of Food and Agriculture

Mtoe	Million tonnes of CO2 equivalent
NPA	National Petroleum Authority, Ghana
OECD	Organization for Economic and Corporate Development
RD&D	Research, Design and Development
TLA	Total land area
USA	United States of America

1.0 Introduction

High dependence on fossil fuels has been the norm in the past and may continue even in the future in the business-as-usual (BAU) scenario. This in turn has led to two grand energy challenges of our times, namely the security of energy supply and the climate change problem. The transport sector, contributing about a quarter of global CO_2 emissions, is the most fossil-fuel dependent sector of all. Limited substitutes for oil in transport and poor adaptability of mitigation options like Carbon Capture and Storage (CCS) and geo-sequestration to this sector propagates the tendency to follow the business as usual path, thereby posing a real future challenge [1].

In this context, bio-fuels have been suggested as a solution to achieve supply security through fossil fuel substitution and to abate climate change. Since 1990s, the domestic bio-fuel sector was actively supported in North America and Europe as well as in other countries, leading to a significant growth in bio-fuel use globally. According to Renewables 2014 - Global Status Report [2], global ethanol production reached 87 billion litres while about 26 billion litres of biodiesel were produced in 2013, thereby contributing about 3% of road transport fuel demand [2].

However, increased bio-fuel production also led to the debate about sustainability of this alternative that lie at the interface of agriculture and energy. The food crisis in 2007-08 and the resultant rise in commodity prices fuelled the bio-fuel versus food security debate. In addition, issues of land use change, deforestation, loss of biodiversity and possible increase in greenhouse gas emissions were also debated [3]. It has also been argued that while a rapid increase in biofuel production can bring in an agricultural renaissance thereby offering employment and income generation opportunities that can reduce poverty incidence, there is also the possibility of loss of access to land by the poorer groups, particularly in countries where the appropriate governance systems are not in place [4].

With its Bioenergy Policy, Ghana seeks to ensure energy security, save foreign exchange, create jobs and contribute to climate change mitigation through the integration of 20% biofuels into transport fuels by 2030. But at present the country does not use bio-fuels at all, although the country heavily relies on biomass-based energies to meet its energy needs. The question then is whether Ghana can achieve its bio-fuel targets given its initial condition. Although other country cases have appeared in the literature, there is limited academic research on Ghana's bio-fuel policy for the transport sector. Duku et al. [5] analysed the bio-fuel potential in Ghana but did not consider the policy target of the government. This paper attempts to bridge this gap by undertaking a critical analysis of bio-fuel supply chain in Ghana.

The paper is organised as follows: the second section presents a review of relevant literature on biofuel policies and country cases. Section 3 presents the estimation of biofuel demand in Ghana up to 2030. Section 4 presents the supply-side analysis and finally section 5 presents the policy implications and concluding remarks.

2.0 A brief review of literature on biofuel policies

According to Ref [2] at least 63 countries used regulatory policies in 2013 to promote biofuels for transport and Ghana is one of the African countries that is actively promoting biofuels. A wide variety of feedstocks has been used to produce biofuels but a few dominant feedstocks can be identified in any given country, led by the specific support schemes. For bioethanol, either starch crops (e.g. maize, wheat and cassava) or sugar crops (e.g. sugar cane, sweet sorghum, and sugar beet) are used, with sugar cane in Brazil and maize in the USA being the dominant examples. Similarly, oil crops (e.g. rapeseed, oil palm, sunflower seed, jatropha, and soybean) are used for biodiesel, with oil palm in Indonesia and Malaysia and rapeseed in the EU as dominant feedstocks for biodiesel [3].

Brazil invested in bioethanol since the first oil shock in 1973 as a reaction to rising oil prices and invested in ethanol through its National Alcohol programme to mitigate oil supply security concerns. The favourable climatic condition for growing sugar cane (plentiful rain, and dry winter) and the massive government support for infrastructure development and research turned Brazil into a world leader in bioethanol production. Although sugar cane is an efficient crop in terms of yield per unit of land, its production requires large volumes of water and a 12 month growing cycle [3]. High water demand along with the potential land use change can impose adverse environmental impacts unless care is exercised.

Maize and rapeseed on the other hand are moderately efficient feedstocks that require high input energy compared to output (i.e. poor input-output energy balance) and compete with food supply. Accordingly, maize has found limited encouragement outside USA while rapeseed got only promoted in EU through subsidy and renewable energy targets [3]. The European Union has been pushing for alternative transport fuels through its policy targets since 2003 and its Renewable Energy Target of 2009 requires at least 10% renewable energy use in the transport sector by 2020 [6]. EU countries use a variety of policy instruments to support the industry – including fiscal incentives (tax reductions and subsidy for agricultural production of biofuels in set-aside lands), economic instruments (such as quotas), and command and control approaches (such as standards). Although tax exemptions were very effective in creating the demand, the loss of revenue to the government has prompted many countries to move to biofuel obligations where the supplier and the final consumers bear the additional cost burden [6]. It is reported in [7] that EU member states have spent between EUR 5.5 and 6.9 billion in 2011 to support biofuels. Ethanol was subsidised between 15 and 21 eurocents per litre while biodiesel received a subsidy between 32 and 39 eurocents per litre [7]. Concerns about the environmental and sustainability credentials of food-based first generation biofuels in the EU have led to some rethinking about the biofuel policy. The emphasis has now shifted to second generation sustainable biofuels, which is in line with its emphasis on greenhouse gas emissions [6]. Given the limited use of biofuels in transport so far, the energy security benefits of EU policy are not significant and the impact on rural development through job creation and income generation opportunities remains unclear [7]. Similarly, Searchinger et al. [8] argued that the GHG benefits of corn-based ethanol in the USA would pay-back emissions from land-use change in 167 years. Over a 30 year period, GHG emissions from corn-ethanol will be double of those from gasoline for each kilometre driven, when land-use change is considered [8].

Palm oil, in terms of yield per unit of land, is the most efficient source for biodiesel and most of the production is located in Malaysia and Indonesia at present [3]. Both the countries enjoy relative abundance of the feedstock due to large plantation areas, which in turn leads to a competitive cost advantage compared to other producers of biodiesel [9]. However, the expansion of palm oil plantation in both countries has resulted in loss of forested areas and the consequent loss of biodiversity [9].

To avoid conflicts with food supply, some countries have adopted non-food based bio-fuel policies. China for example has imposed a ban on biofuel production from food crops while

India is promoting alternative non-food crop feedstocks such as jatropha. However, Achten et al. [10, 11] argue that although jatropha is a wild plant, it requires inputs like any other crop to achieve high yield and profit-motivated investors may move away from marginal lands to agricultural or forest land to reduce financial risks, thereby damaging food security and environmental credentials of the crop. It is suggested that the carbon debt linked to conversion of arid and semi-arid land for jatropha cultivation, biofuel production and use may be difficult to repay within a human generation [10].

3.0 Bio-fuel demand in Ghana by 2030

Assuming that Ghana is going for a biofuel target, this section estimates the biofuel demand until 2030. As the objective is to displace fossil fuels for transport, this section first considers the transport fuel demand trend in Ghana, followed by an estimation of demand up to 2030 using an econometric model. Finally, the biofuel target is estimated.

3.1 Consumption trend

In 2012, a total of 3.2Million tonnes of petroleum products were consumed in Ghana. 52% of this was diesel whilst gasoline accounted for 31%. Gasoline has suffered a loss of share from 35% in 2000 while the diesel share has increased from 45% [12]. However, in absolute terms both the fuels have recorded an increase in demand: gasoline consumption increased from 0.52Million tonnes in 2000 to 0.99 Mt in 2012 whilst diesel increased from 0.67Mt to 1.66Mt over the same period. Figure 1 captures the consumption trend by fuel while Fig. 2 provides the petroleum product consumption mix for 2010 [12].

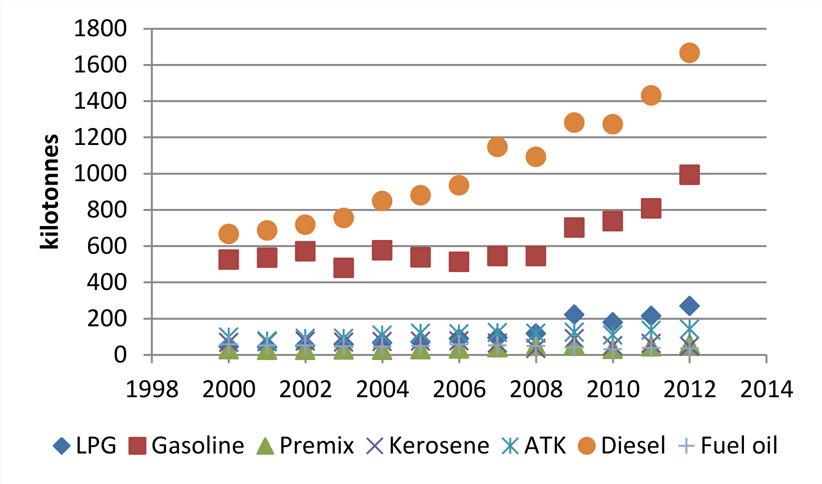

Fig. 1: Consumption trend of petroleum products in Ghana

Data source: [12].

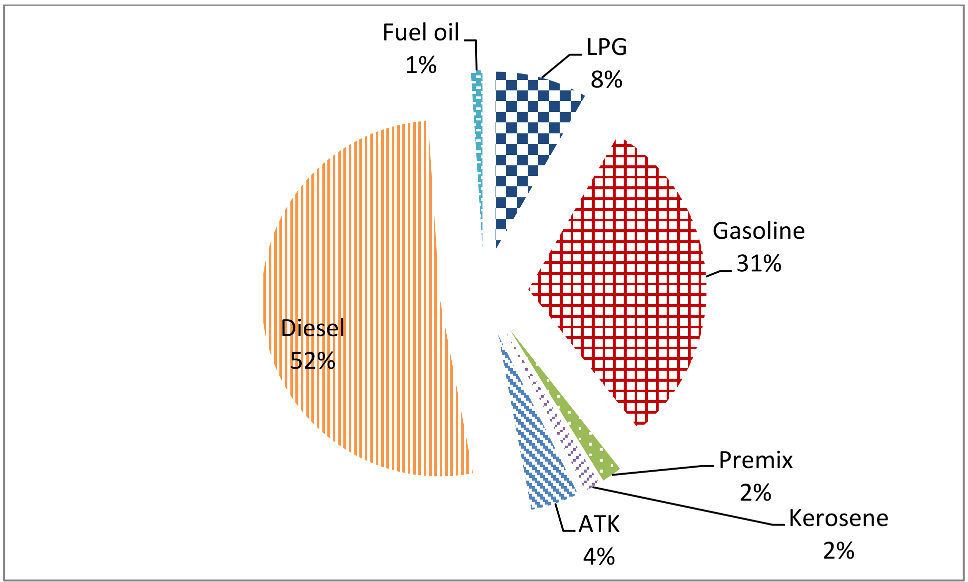

Fig.2: Ghana's Petroleum product mix, 2012

Data source: [12]

Note: LPG – Liquid petroleum gas, ATK – Kerosene for aviation.

Ghana's improved economic performance in recent years has clearly influenced its transport fuel demand. Since 2000, Ghana has benefited from an accelerated economic growth that resulted in higher economic wealth in terms of per capita income. As Fig. 3 indicates, the nominal gross domestic product per capita increased four-fold between 2000 and 2012.

Greater freight and passenger movements fuelled by increased economic activity can therefore be considered as the driver behind increased gasoline and diesel demand in the country.

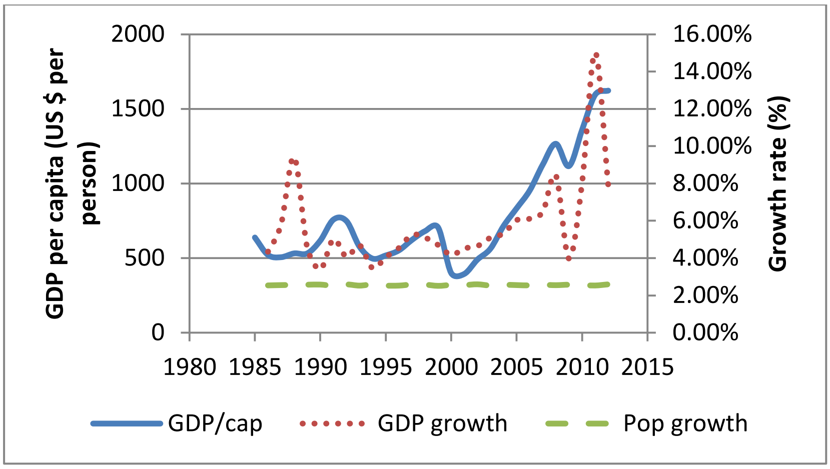

Fig. 3 Ghana's economic performance indicators (selected)

Note: Pop – population

Data source: [13]

3.2 Demand forecasting

For transport demand analysis, three types of generic models are found in the literature: a) identity models and b) structural models and c) the market-share approach. The identity models consider the demand for a transport fuel to be equal to the product of vehicle utilisation rate and total stock of vehicles. The structural approach on the other hand considers the demand for the transport services and derives the demand for energy related to those transport services as a derived demand. The market-share approach considers the inter-fuel substitution possibilities [14]. However, due to lack of adequate data for such detailed analysis in the country, a simple econometric model based on [15] was used as indicated below.

$$ln(TC) = a_0 + a_1 ln(GDP) + a_2 ln(P) + a_3 ln(TC_{-1}) \quad (1)$$

The gasoline share given by

$$ln(GC/TC) = b_0 + b_1 lnGP + b_2 lnDP + b_3 lnGDP + b_4 ln(GC/TC)_{-1} \text{ .... (2)}$$

Where TC is the total consumption, GC is gasoline consumption, DP is diesel price, GP is gasoline price, P is the weighted average price of diesel and gasoline, GDP is GDP per person and TC_{-1} is the previous year's consumption. Using energy data from IEA's Extended Energy Balance, IMF World Economic Outlook 2013 and energy prices from Ghana Energy Commission for the period between 1989 and 2011, a simple econometric analysis was performed to estimate the above model. The estimated results are presented in equations 3 and 4 (see table 1 for details). The specification for total transport fuel demand behaves as expected – with a price elasticity of -0.215, and GDP elasticity of 0.266 in the short run. All the coefficients are statistically significant at 5% level and the model does not show any sign of auto-correlation. The lag term influences the overall demand quite significantly as well. However, the share model with GDP and lagged share terms did not behave well. The specification with oil prices yielded better outcome and was retained.

$$ln(TC) = -1.639 + 0.266\, ln(GDP) - 0.215\, ln(P) + 0.971\, ln(TC_{-1}) \text{ .... (3)}$$

$R^2 = 95\%$; DW statistic = 2.42

$$ln(GC/TC) = -0.821 + 0.703\, ln(GP) - 0.831\, ln(DP) \text{ ...... (4)}$$

$R^2 = 49\%$;

Table 1: Matrix of coefficients from regression analysis

Coefficient	*Value*	*Standard Error*	*t Stat*	*P-value*
a0	-1.639	0.750	-2.185	0.042*
a1	0.266	0.102	2.597	0.018*
a2	-0.215	0.090	2.375	0.029*

a3	0.971	0.065	14.814	0.000*
b0	-0.821	0.045	-18.008	0.000*
b1	0.703	0.361	1.944	0.067**
b2	-0.831	0.337	-2.468	0.024
b3	Dropped			
b4	Dropped			

* significant at 5% confidence interval; ** - significant at 10% confidence interval;

For forecasting purposes, three GDP growth scenarios, namely Business-as-usual (BAU) of 5.0% per year based on historic data, a high economic growth secnario (HGS) of 8.0% per year and a moderate growth scenario (MGS) of 6.5% per year are cosidered. As indicated above, Ghana has registered high rates of economic growth in recent years, particularly since 2010 when it became an oil producing country. The possibility of maintaining such high rates of economic growth is captured in the high scenario. On the other hand, the long-term average rate of economic growth is about 5%, which is used as the base case. An intermediate rate of growth is considered in the medium growth scenario. For fuel price, the historical price rise rate between 1989 and 2011 is taken. This amounts to 7% rise in composite price per year. Population forecast for the period is taken from UN Population Prospects 2012 (median variety).

Using the estimatted equations the consumption of transport fuels (gasoline and diesel) up to 2030 is estimated whilst equation (4) yielded the share of each fuel by that year. The demand forecast is shown in Fig. 4.

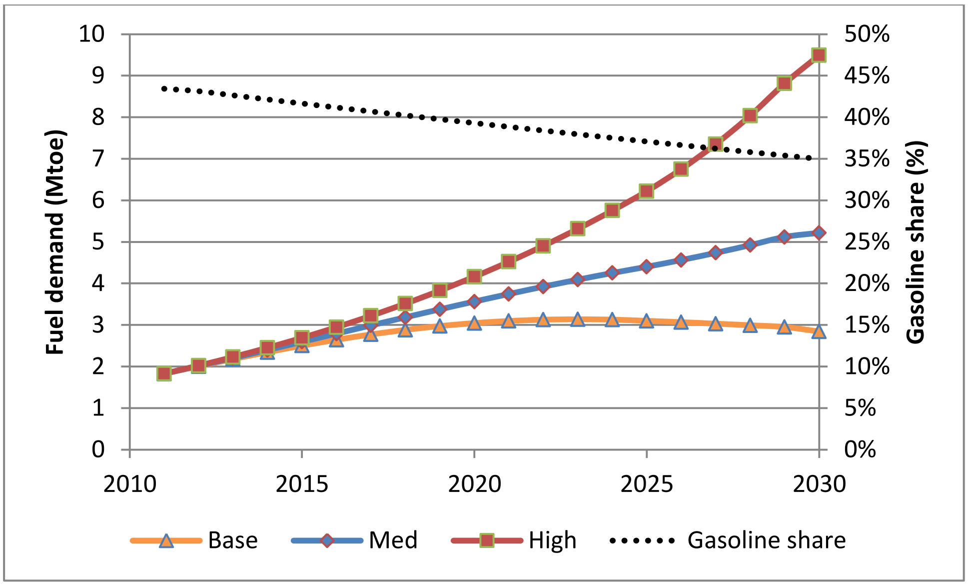

Fig. 4: Transport sector fuel demand forecast in Ghana up to 2030

Clearly, the transport fuel demand can explode if the economy maintains its high growth consistently over two decades. The more likely case of a moderate growth over two decades will also more than double transport fuel demand in Ghana while the business-as-usual case shows a demand saturation at around 3 Mtoe. The rise in price assumed in forecasting and a low GDP elasticity of transport fuel contribute to such a demand pattern.

From total transport fuel demand forecast (in ktoe) for 2020 and 2030, the gasoline and diesel demand (in million litres) is obtained considering each product's share in total demand, weight–to-volume conversion ratio, and energy content of each product. Table 2 indicates that gasoline demand can vary between 2 to 3 billion litres in 2020 depending on economic growth and increasing to 6 billion litres in 2030 in the high growth scenario. The diesel demand will remain higher than gasoline, and the difference can be significant in 2030 under the high economic growth scenario.

The biofuel target is taken as 20% of the sum of gasoline and diesel demand in a given year. The composite biofuel target was considered as the overall target of 20% is what matters from a policy perspective. This can be achieved using different proportions of ethanol and biodiesel according to the relative ease of production of each type in the country. Table 2 shows that the demand for liquid bio-fuel can vary between 915 million litres and 1250 million litres in 2020 and 840 million litres and 2800 million litres in 2030. The decrease in biofuel demand in the base case follows from the saturation of fuel demand indicated earlier.

Table 2: Biofuel demand forecast up to 2030

Year	Scenario	Total demand (ktoe)	Gasoline (Ml)	Diesel (Ml)	Bio-diesel target (Ml)
2020	Base	3044	2150	2424	915
	Med	3563	2517	2837	1071
	High	4162	2940	3314	1251
2030	Base	2844	1788	2425	843
	Med	5217	3280	4450	1546
	High	9491	5968	8095	2813

Two important implications from the above are that:

- The demand for biofuel is likely to be significant, considering the present status of production in Ghana. The food-fuel competition is a critical factor that must be considered in any policy decision about the development of biofuels
- The local resource capacity (human, material) of the country involved in terms of resources must determine the choice of the appropriate technology option.

4.0 Analysis of biofuel supply in Ghana

4.1 Agricultural land area

Biofuel production from agricultural feedstock is dependent on land, water, and other resources. Food- fuel competition takes place at two levels: for land and for price in the market. Two alternative cases could evolve:

1. If the biofuel is produced from crop feedstock (e.g. corn and cassava), competition for land may be less prominent but diversion of food grains for fuel leads to price competition that can have a damaging impact (higher social cost) on society if not properly managed using a comprehensive regulatory framework.
2. On the other hand, where non-crop (e.g. Jatropha) feedstock is selected, food-fuel price competition is eliminated but food and fuel now compete for limited land. Thus land becomes the more critical factor.

Also, overall, land is often a limiting factor to biofuel development in that even where it exists, local agro-ecological factors such as soil fertility, and climate could limit feedstock output. Success in biofuels development therefore depends on how well the above competitions and limitations are managed to mitigate the social impacts.

Ghana has a total land area (TLA) of 23.9 million hectares of which 57% constitutes the agricultural land area (ALA). 58% of ALA is under cultivation with only about 0.4% under irrigation as shown in Fig. 5.

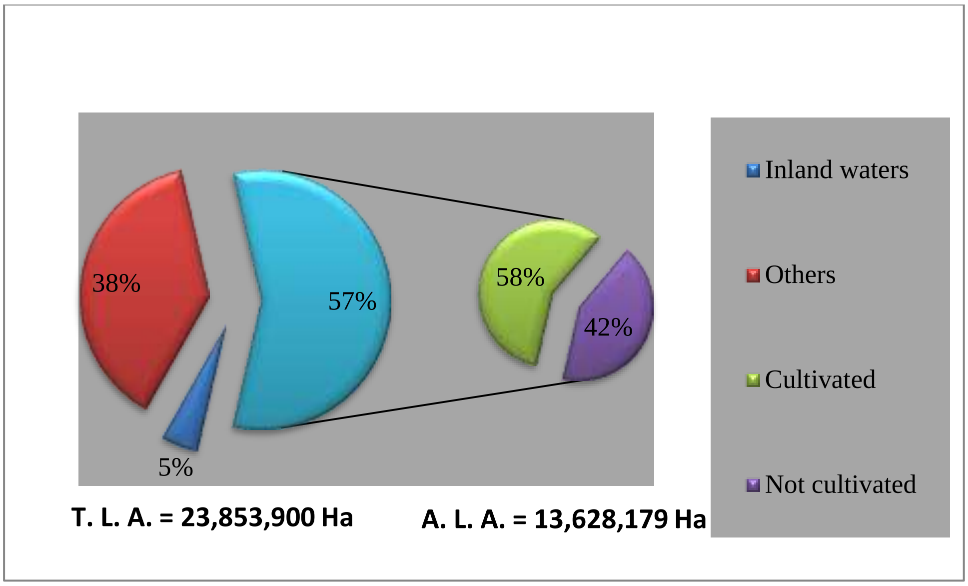

Fig. 5: Ghana land use status in 2010

Note: TLA – total land area, ALA – Agricultural land area

Data source: [16].

The expansion of agricultural production for both food and feedstock supply is therefore limited to the uncultivated area (about 5.9Mha). “Others” represent forest reserves and savannah woodland among others, conversion of which for agricultural use may happen under biofuel pressure.

4.2 Feedstock options

Ethanol can be produced from a large variety of sugary and starchy crops such as wheat, sugar beet, sugarcane, corn, and cassava. Ghana, by virtue of agro-ecology, is in a suitable position for biofuel production. Major feedstock used for biofuels such as maize (corn), cassava, palm oil and sugarcane are already grown for food. The analysis of feedstock requirement is primarily based on suitable land area for crop feedstock whereas that of Jatropha is based on marginally suitable land for the following reasons:

1. The economic viability of jatropha as fuel crop is yet to gain scientific justification [11]. Although it is touted with much potential to ease the food-fuel war of conventional technologies, jatropha is yet to validate this credential. It is claimed to be “drought resistant” and can grow on marginal land, yet field trials do not always corroborate these claims. Input requirements are not any better than other crops; yields vary widely: less than 1.25 tonnes per hectare in some cases whereas up to 7 tonnes/ha of yields have also been realized under optimized conditions.
2. Focusing on food crop feedstock takes care of food security concern.
3. Jatropha requires long time tie-down of land due to long lifespan of the plant and committing crop land to its cultivation should be carefully considered.
4. Jatropha plantation requires huge capital commitment upfront and payback starts only after about three years onwards. It will be difficult to use similar incentives as crop feedstock therefore to drive its development.

For these reasons, we have considered the biofuels target solely based on the food crops and jatropha is only considered to be grown on marginal lands as supplement.

4.3 Biofuel yields

Different feedstocks have different yield characteristics depending on the agricultural yield (land-use efficiency) on one hand and the technological yield (conversion efficiency) on the other. IEA global averages indicate that sugar cane yields 1.8 times the biofuel yield of corn per hectare. Similarly, palm oil produces 5.3 times the biodiesel yield of soybean [17]. As shown below (table 3), even though corn has a higher conversion rate, cassava and sugarcane with higher yields, actually produce more ethanol annually.

Table 3: Comparison of ethanol yield from different crops

Crop	Yield (tonne/ha/year)	Ethanol conversion rate (l/tonne)	Yield (l/ha/year)
Cassava	40	150	6000
Sugarcane	70	70	4900
Corn	5	410	2050
Wheat	4	390	1560

Source: Adapted from [17].

Studies in Ghana have shown that there is a huge gap between the average and achievable yields of the selected crops due to poor farming practices and low inputs. Farming is mostly on a small holder family basis with cutlass and hoe as the main tools and about 90% of farms are less than 2 hectares in size. Large farms are mostly associated with cash crops which are cultivated on plantation basis [16]. Figure 6 shows the depth of this efficiency gap.

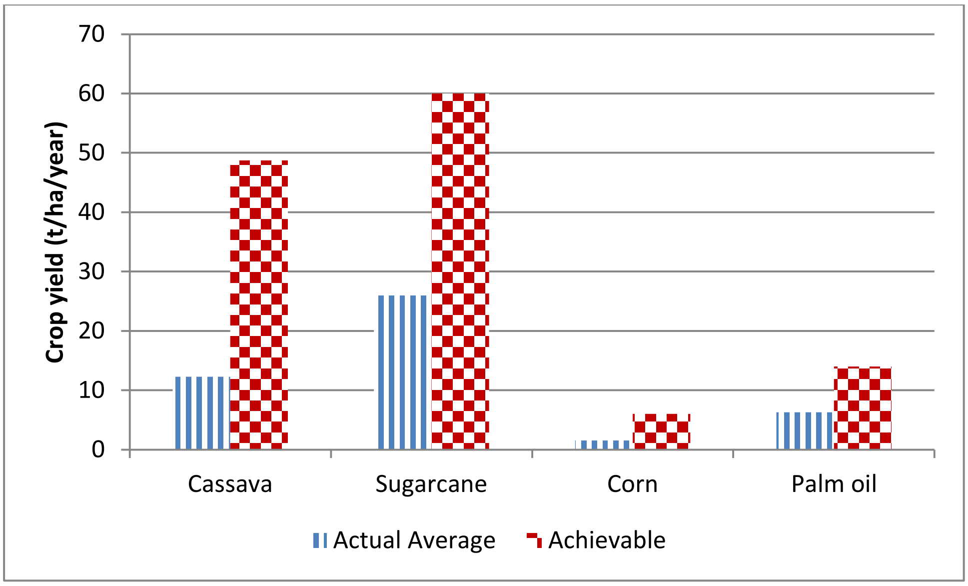

Fig. 6: Land use efficiency gap

Source: this study

Moreover, farmers rely on rain-fed traditional agriculture with little mechanization, fertilizer, improved seeds and after harvest services. Increased output has often meant increased use of land as there is little improvement in crop yield per hectare. The implication is that Ghana is not self-sufficient in some of the above selected crops; but it also offers the opportunity for meeting targets without necessarily using up more land. A food Balance Sheet analysis exposed the level of deficiency for the crops, especially maize (see Fig. 7).

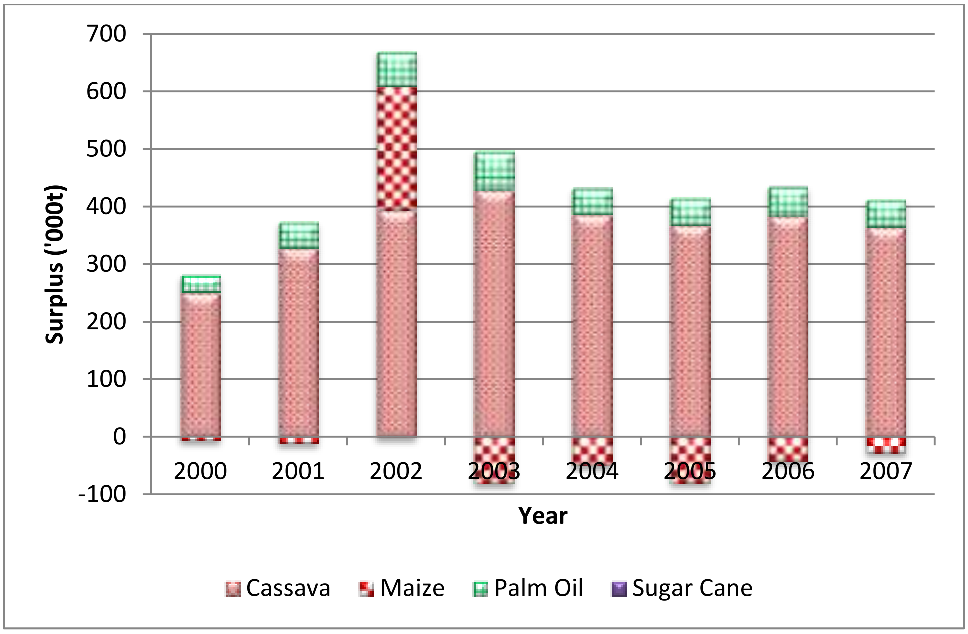

Fig. 7: Commodity balance in Ghana

Data source: FAO statistics

4.4 Biofuel Supply scenarios

Since there is currently no biofuel production in Ghana, the supply scenarios are based on following assumptions:

- The historical production and consumption growth rates of crops are used to estimate the production and consumption in 2020 and 2030;
- The area required for production is estimated using crop yield data and the additional cropping area requirement is estimated by difference from 2010 cultivated area;
- The surplus crop availability is determined taking the difference between production and consumption; this is used for ethanol production and the ethanol production is estimated using the ethanol conversion rates for the crop.

- The reverse process is used to calculate the production required, and the extra cropping area required to meet the biofuel target under different scenarios.
- The same process is repeated using different yield improvement factors as well.

As our objective is to find out whether or not the biofuel targets can be met, we verify against the high growth scenario where the demand is higher. Table 4 provides the results. As can be seen, Ghana is likely to meet its 20% biofuel target both in 2020 and 2030. Cassava and palm oil are likely to be the main feedstocks in 2020 but palm oil becomes the dominant feedstock by 2030.

Table 4: Bio-fuel Supply in high demand scenario

Forecast	**2020**			**2030**		
Crop	Area (million ha)	Crop yield (Mt)	Biofuel yield (Ml)	Area (Mha)	Crop yield (Mt)	Biofuel yield (Ml)
Cassava	1.85	2.49	377.90	2.76	5.93	907.31
Maize	1.54	0.48	197.31	1.93	0.86	360.76
Palm	0.32	1.91	675.57	0.67	4.32	1543.89
Sugarcane	0.01	0.00	0.23	0.01	0.01	1.05
Total	3.71	4.88	1251.00	5.36	11.13	2813.00

Clearly, the area cultivated stands out as the main influencing factor to the quantity of biofuel output. The land-use efficiency (yield per hectare) is another important factor that energy policy should be focused on if the target is to be achieved. Because land is a limiting factor, analysis of area requirements under different yield improvements for high and medium economic growth scenarios were done in order to exploit the enormous gap between the average and achievable yields under the following assumptions:

1. Food is given priority and any biofuels will be produced from surplus supply after domestic consumption.

2. Food consumption is expected to grow in the coming decades due to population and economic growth. This gains more importance as the country strengthens its fight against malnutrition and hunger issues in a growing economy.
3. Overall yield improvements are distributed to study crops based on their yield gap on the assumption that the larger the yield differential between the average and the attainable, the easier it is for more improvement and vice versa.

Figure 8 shows the results of the analysis. The bars indicate area of land required by each feedstock to meet the target under various yield improvements of BAU, 10%, 20%, 50% and achievable. Due to agro-ecological factors, the ALA has been surveyed and put into land suitability maps and tables for various crops in the country. Though these areas would overlap for different crops, it enables one to determine the total ALA available to each crop and thus aids proper planning for the various energy crops under study. A_{suit} is the total suitable land area for each crop. It is the sum of land areas designated as “very suitable”, “suitable” and “moderately suitable”. “Marginally suitable” areas were left for Jatropha consideration.

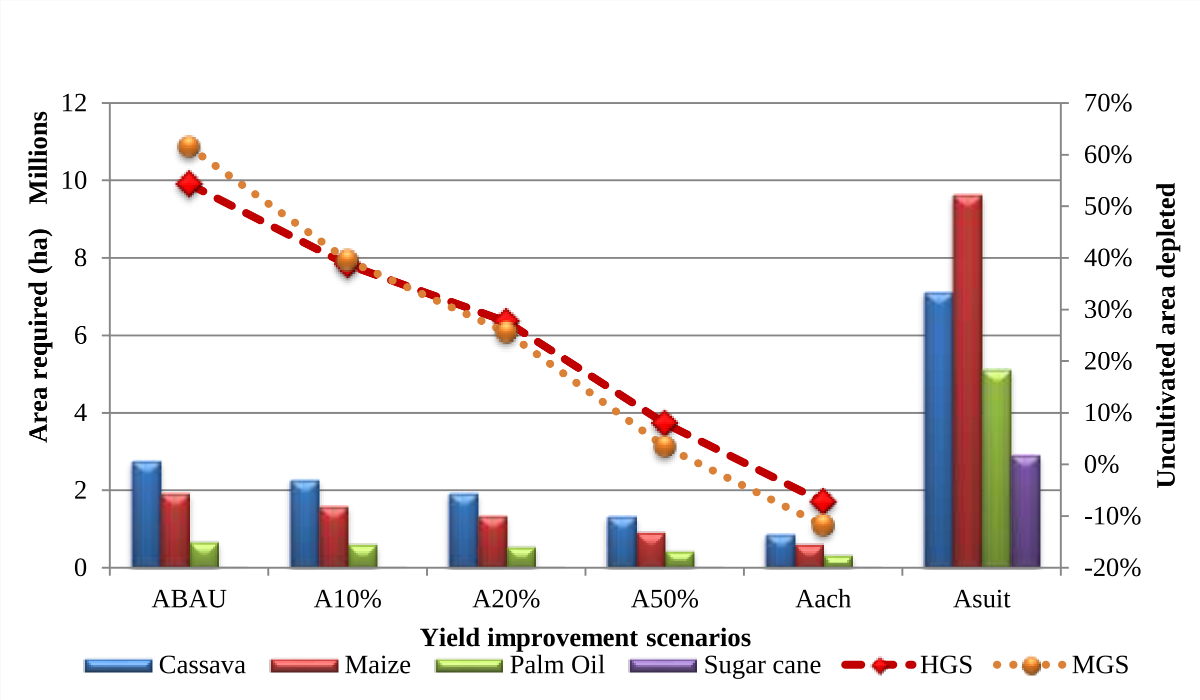

Fig. 8: Land use requirement in Ghana to meet bio-fuel production target by 2030

The series graphs show the level of depletion of the uncultivated available land (ALA) under high and medium growth scenarios (HGS and MGS). The result is that, under BAU yields, the crops under study will deplete 54% and 61% of the uncultivated ALA by 2030 under HGS and MGS respectively; more than doubling their land coverage of 28.36% (2.2Mha) in 2010. However, the additional area requirement could reduce to only 8% and 3% under HGS and MGS respectively from the 2010 baseline if even half of the achievable yield potential could be realized by 2030. Ultimately, even 7% and 12% of cultivated area in 2010 could be freed for other uses or fallow under HGS and MGS respectively if the overall achievable yields level could be attained.

4.5 Determinants of bio-fuel output

The quantity of biofuel, B obtainable from a cropped feedstock, can be expressed as:

$B = A.\frac{Q_i}{A_i}.\frac{V_i}{Q_i}$ .... (5)

Where A is the total planted area such that A = $\sum A_i$ and A_i is the area of land portion I (in hectares); Q_i is the quantity of feedstock obtained from area A_i (in tonnes); and V_i is the volume of biofuel obtainable from energy crop quantity Q_i (in litres).

Equation 5 can be expanded as below and decomposed to identify which of the factors influence biofuel production and therefore should inform biofuel policy path:

$B = \sum A * \frac{A_i}{A} * \frac{Q_i}{A_i} * \frac{Q_{ij}}{Q_i} * \frac{V_{ij}}{Q_{ij}} = \sum_{ij} A * S_i * I_i * M_{ij} * U_{ij}$ .... (6)

Where V_{ij} is the biofuel volume from feedstock j on biofuel land i; Q_{ij} is the quantity of feedstock j on biofuel land i and $Q_i=\sum_j Q_{ij}$. S_i is the structure of agricultural land, I_i is the crop yield intensity which measures the land-use efficiency, M_{ij} is the crop mix and U_{ij} is the conversion efficiency dependent on the technology. The influence of each factor on biofuel production can be estimated if the component data is available.

Table 5 lists the area requirements, feedstock yield per unit area and biofuel yield per tonne of feedstock to meet the pre-estimated biofuel targets for the years under consideration and the parameters required for decomposition of equation 13.

Table 5: Data for decomposition analysis

Data for decomposition in 2020						
Crop	B (Ml)	A (Mha)	S	I	U	M
Cassava	377.90	1.85	0.50	1.3518	152	0.3021
Maize	197.31	1.54	0.41	0.3102	414	0.1577
Palm	675.57	0.32	0.09	5.9479	354	0.5400
Sugarcane	0.23	0.01	0.00	0.4705	71	0.0002
Total	1251.00	3.71	1.00	8.0803	990	1.0000
Data for decomposition in 2030						
Crop	B (Ml)	A (Mha)	S	I	U	M
Cassava	907.31	2.76	0.51	2.1486	153	0.3225
Maize	360.76	1.93	0.36	0.4478	418	0.1282
Palm	1543.89	0.67	0.13	6.4462	357	0.5488
Sugarcane	1.05	0.01	0.00	1.9029	71	0.0004
Total	2813.00	5.36	1.00	10.9455	1000	1.0000

Data source: based on table 4 and supporting data from FAO Stat.

The decomposition results are shown in Fig. 9 and table 6.

Table 6: Factor decomposition results of biofuel production by feedstock

Crop	w	Land	Str	Yield	Tech	Mix	D (by crop)
Cassava	0.3136	0.1157	0.0105	0.1453	0.0031	0.0206	1.34
Maize	0.1405	0.0518	-0.0200	0.0516	0.0014	-0.0291	1.06
Palm	0.5450	0.2010	0.2001	0.0439	0.0054	0.0088	1.58
Sugarcane	0.0003	0.0001	-0.0001	0.0004	0.0000	0.0002	1.00
Total	0.9994	0.3686	0.1906	0.2411	0.0100	0.0005	
D (by factor)		1.45	1.21	1.27	1.01	1.00	2.25

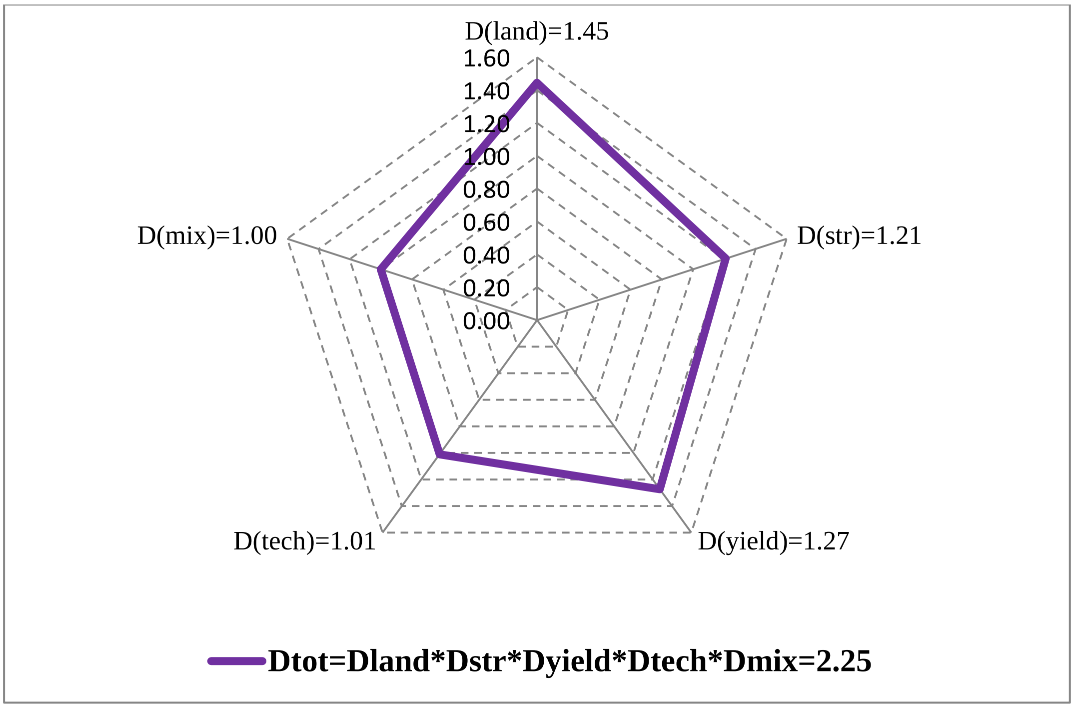

Fig. 9: Decomposition result of biofuel production

Figure 9 shows that 45% of the increase in total biofuel output between 2020 and 2030 comes from land use which makes land availability a critical factor to the attainment of the bioenergy target. Another 27% of the increase comes from yield improvement whilst crop mix and conversion technology explain 0% and 1% respectively. This makes the assumed yield gap mix concept a positive one since it leads to increase in biofuel output though finding the actual optimal crop mix could be tricky. Structural changes in land use could result in a 21% increase in biofuel production which suggests that adjusting the land allocation pattern for crop cultivation can help in producing more biofuel. Limited role played by technology is due to the assumption that no springboard technological advancements are expected in the conversion technologies within the period based on the IEA Technology Roadmap [18].

For a full picture of the nature of influence of all factors on the biofuel development, the decomposition by crop type was also done as shown by figure 10 below.

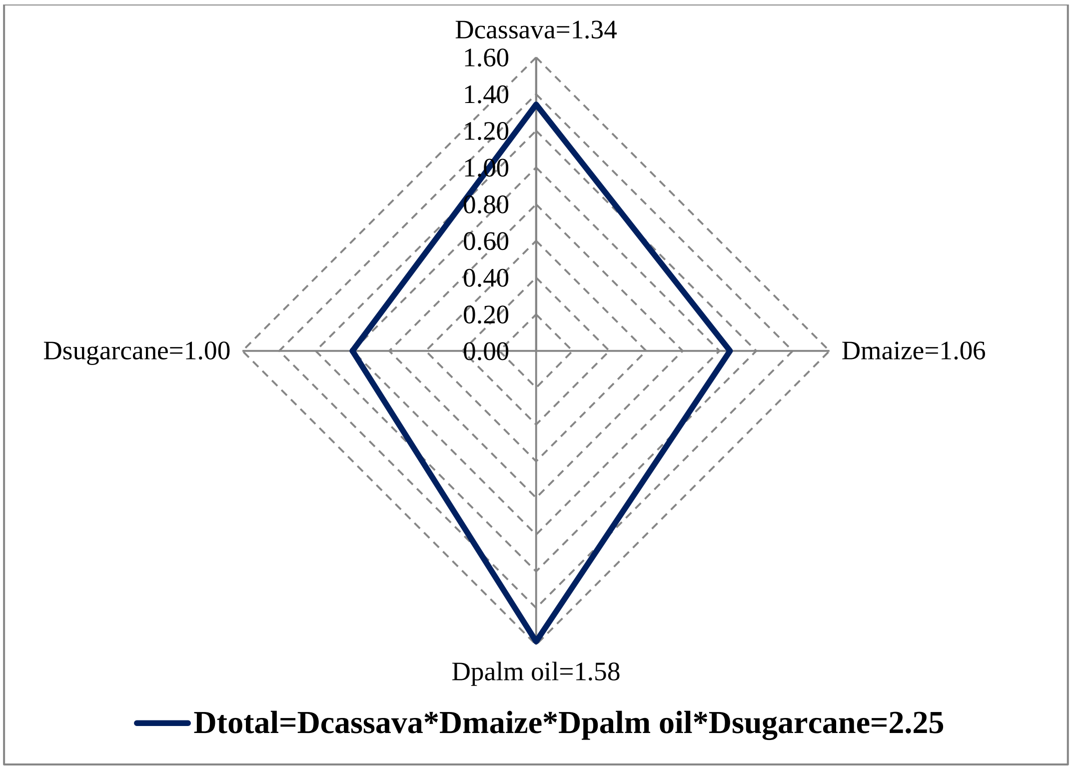

Fig. 10: Factor decomposition of biofuel production by crop feedstock

Figure 10 indicates that 58% of the increase in biofuel production between 2020 and 2030 resulted from palm oil, making it the favourite crop in trying to achieve the biofuels target. Cassava also led to a 34% increase in the biofuel output making it the next crop with a higher potential to achieving the target. Maize records a 6% growth while sugarcane does not contribute to any additional biofuel supply. This results from a combination of factors such reduction in available surplus due to increase in crop demand for food, lower biofuel yield per unit of crop, lower crop yield per hectare of land and possible limitations on suitable land for the crop as explained in the next section, inter alia.

It therefore means that policy decisions should be aimed at yield improvement through mechanization and increased inputs. With that, yields closer to achievable can be obtained from fields making it easier to meet the bioenergy target without much stress on ALA.

5.0 Conclusions

The main aim of the paper was to find out whether Ghana's biofuels target is achievable or not. Based on our transport fuel demand estimation and considering a biofuel target of 20% in 2020 and 2030, we find that it is indeed possible for Ghana to achieve the target. Palm oil is likely to be the main source of biofuel in the country, followed by cassava. Surprisingly, sugar cane is unlikely to contribute much to the biofuel supply. However, care must be exercised in promoting biofuel in the country. Growth in biofuel output is likely to come at the cost of additional land use. Over expansion of cultivated area has the potential to offset any carbon credits that will accrue under biofuels use.

Yet, given the huge gap between the current yields and achievable yields, the country could also focus on a significant improvement of crop yields to avoid sacrificing too much land to biofuel production. However, since about 90% of farms are small-scale family type, implementation of yield improvement measures will be very difficult due to the large number of diffused farming population to be reached with such policies. Biofuel projects therefore should aim at an integrated approach where the biofuel company produces their own feedstock through mechanized farming.

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